Interactive Configuration of High Performance Renovation of Apartment Buildings by the use of CSP

Vareilles, E.; Thuesen, Christian; Falcon, M.; Aldanondo, M.

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É. Vareilles, C. Thuesen, M. Falcon and M. Aldanondo

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Observations

Buildings vs Total Energy Consumptions :

- 31% in Japan [Center, 2012],
- 36% in USA [Council, 2013],
- 37% in UE [Perez-Lombard et al., 2008].

Increased and greater than other major sectors : industry and transportation

Observations

New dwellings annual rate in UE : 1.1% [Poel et al., 2007]

Observations

Energy consumption regulation

- to retrofit existing buildings,
- to reduce their energy consumption,
- to assist the retrofit process by DSS [Juan et al., 2010].

Observations

Actual Retrofit Limitations [Falcon and Fontanili, 2010]

- very dependent on hand-made methods,
- no quality guaranty

CRIBA Project Aims

- to industrialize high performance thermal renovation,
- to develop a new method for 3D building survey and modelling,
- to develop a configuration system to support the retrofit,
- to test the solution on a working site.

CRIBA Solution Concept

A complete new envelope

The whole building is wrapped in a new complete envelope composed of efficient and multifunctional panels.

Excerpt of a report about CRIBA that was broadcast by BFM TV Green Business on February 2013

`CRIBA-extract.mkv`

CRIBA Project Synthesis

Consortium

- Syrthéa, Toulouse(31),
- Millet, Bressuire(79),
- Mines Albi-Carmaux(81),
- OPH des Landes(40),
- Aldés, Toulouse(31),
- Fly-n-Sense, Merignac(33),
- Solarezo, Pontonx(40).

Key Figures

- global budget : 8.8 M €,
- ADEME funding : 2.9 M €
- duration : 3 ans,
- target : 25000 houses/year,
- energy target : $25 kWh/m^2/year$

La Pince, Saint Paul les Dax

Présentation de l'opération

- 110 logements collectifs dont :
  - 14 T2
  - 46 T3
  - 50 T4
  - 60 garages
- Une parcelle d'une contenance totale de 28 735 m² avec une densité de 38 logements à l'hectare
- Un bâtiment R+3 construit en 1975 rassemble 50 logements desservis par 5 entrées regroupant 8 T2, 24 T3 et 18 T4.
- 4 bâtiments R+3 (1977 et 1978) de 15 logements regroupant 2 typologies différentes (7 T3/8 T4 ou 3 T2/4 T3/8 T4)

La Pince, Saint Paul les Dax

Photos

CSP-based Configuration System

Functional Scope

- edit BOM,
- define assembly process,
- estimate renovation global cost,
- estimate thermal performance,
- propose different façade layouts,
- compare different renovation solutions.

Out of Scope

- optimize solutions,
- produce accurate quotations,
- produce command scripts,
- take into account air ducting in its 1^{rst} version,
- interface itself with 2D/3D CAD software.

GBOM

Bill of Material

List of components, sub-components, sub-assemblies, and their quantities to manufacture an end product with options and variants.

CRIBA BOM

- end product : new thermal envelope
- sub-assemblies : facade new envelopes
- sub-components :
  - multifunctional panels
  - metal fasteners : to fix metal profiles, to hang panels or to provide wind bracing,
  - metal profiles, needed when new envelope weight cannot be supported.

GBOM

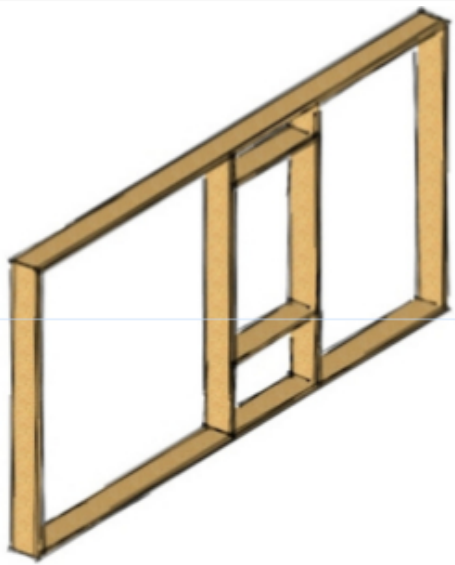
CRIBA Components

- leaves of BOM : configurable components :
  - panels,
  - angles,
  - windows, doors, solar modules and balconies,

Multifunctional Panels

Description

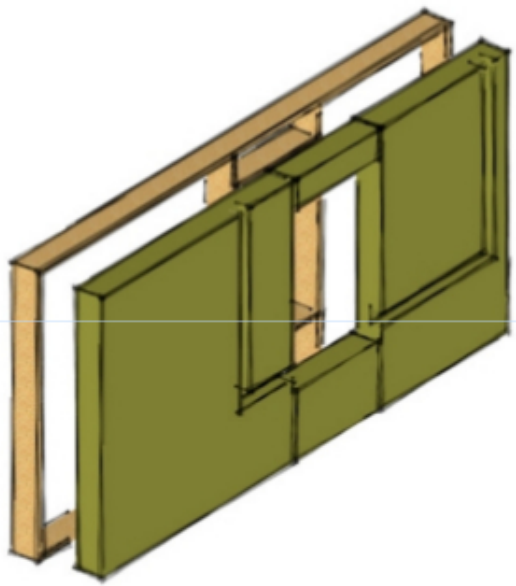
Rigid 2D rectilinear wood rectangle structure

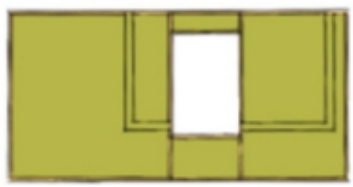


Multifunctional Panels

Description

Filled with insulation

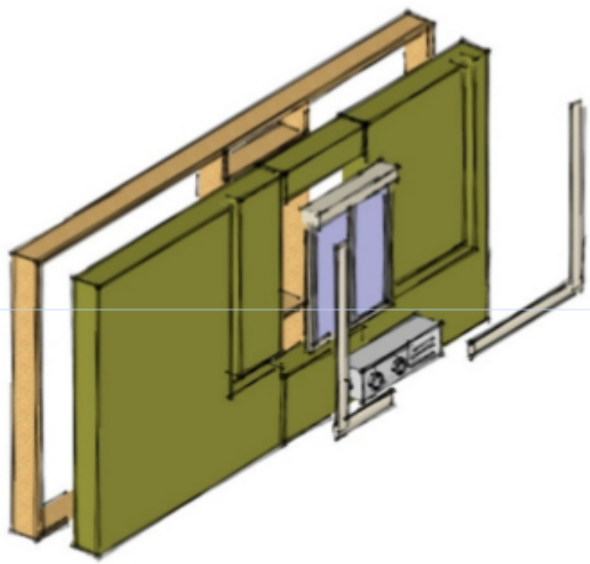




Multifunctional Panels

Description

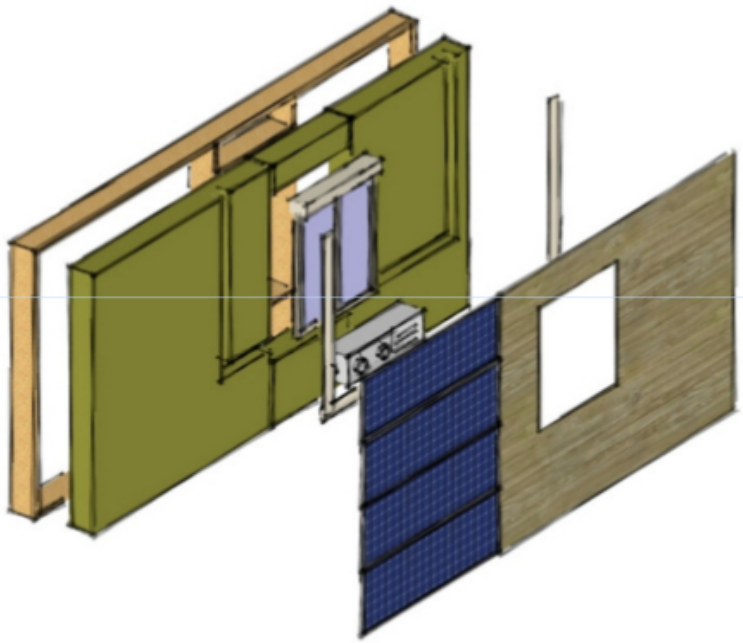
Including windows and doors, CMV and eventually a technical area (for electric shutters or CMV air ducting)

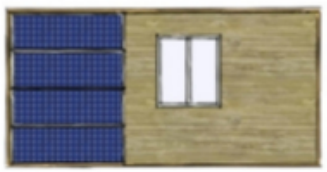


Multifunctional Panels

Description

Including cladding and/or solar modules





Multifunctional Panels

Main variables

- width in mm $[90, 3000]$
- length in mm $[90, 12000]$
- coordinates (abscissa and ordinate),
- insulation thickness in mm $[150, 500]$,
- insulation type (mineral wool or cellulose),
- weight, which depends on dimensions, insulation type, and included components.

Multifunctional Panels

Main variables of included components

We need to know exactly for each of them :

- width in mm $[min_w, max_w]$,
- length in mm $[min_l, max_l]$,
- relative position on the panel (x and y),
- type and reference code.

Minimal distance between panel sides and components position ≥ 90 mm to preserve the panel stiffness.

Angles Description

rigid 3D L-polyomino tetracubes placed at the building corners which cannot include anything.

Main variables

- width in mm $[90, 3000]$,
- right length in mm $[90, 12000]$
- left length in mm $[90, 12000]$
- coordinates (abscissa and ordinate),
- insulation thickness in mm $[150, 500]$,
- insulation type (mineral wool or cellulose),
- weight, which depends on dimensions and insulation type.

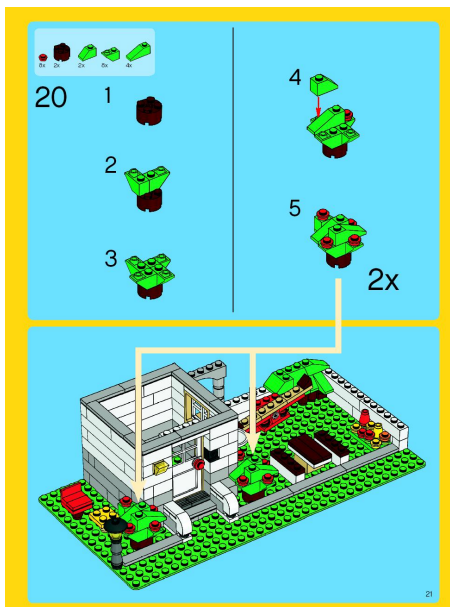
Angles dimensions depend on their adjacent panels dimensions.

Generic Assembly Process

Assembly Process

Set of tasks to be carried out in order to assemble the new frame and envelope all around the building :

- tasks always to be carried out, such as positioning and fixing metal fasteners,
- optional tasks, such as fixing the metal profiles onto the metal fasteners.



Interactive Top-down and 5-step Process

From working site to components

User needs to provide information about :

1. the whole working site (composed of blocks),
2. the block of apartment buildings (composed of buildings),
3. the apartment building (composed of facades),
4. the façades (composed of panels),
5. the configurable components (panels, angles, doors, windows, CMV, etc).

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Interactive Top-down and 5-step Process

Progressive solution configurations

After each user input, the configurator removes inconsistent values and guides progressively the user to a consistent solution.

Working Site Description

Main Variables

- *accessibility* : easy, medium, difficult
- *local atmosphere* : windy, not windy

Impact on BOM and Assembly Process

- accessibility and panels dimensions : difficult access $\Rightarrow$ normal trucks $\Rightarrow$ small panels
- local atmosphere and panels dimensions : wind speed peaks $\geq 80\ km.h^{-1} \Rightarrow$ small panels
- local atmosphere and renovation time : wind speed peaks $\geq 80\ km.h^{-1} \Rightarrow$ non-working periods.

Blocks Description

Main Variables

- *accessibility* : easy, medium, difficult
- *number of buildings* : ≥ 1

Impact on BOM and Assembly Process

- accessibility and panels dimensions : difficult access $\Rightarrow$ hoisting equipment $\Rightarrow$ small panels
- accessibility and panels dimensions : difficult access $\Rightarrow$ hoisting equipment $\Rightarrow$ assembly process

Buildings Description

Main Variables

- *accessibility* : easy, medium, difficult
- *height* : $[min_h, max_h]$
- *Façades Number* : ≥ 1

Impact on BOM and Assembly Process

- accessibility and panels dimensions : difficult access $\Rightarrow$ hoisting equipment $\Rightarrow$ small panels
- accessibility and panels dimensions : difficult access $\Rightarrow$ hoisting equipment $\Rightarrow$ assembly process
- height and panels dimensions : height $\leq 12m$ (four stories) $\Rightarrow$ panels fixed vertically.

Façades Description

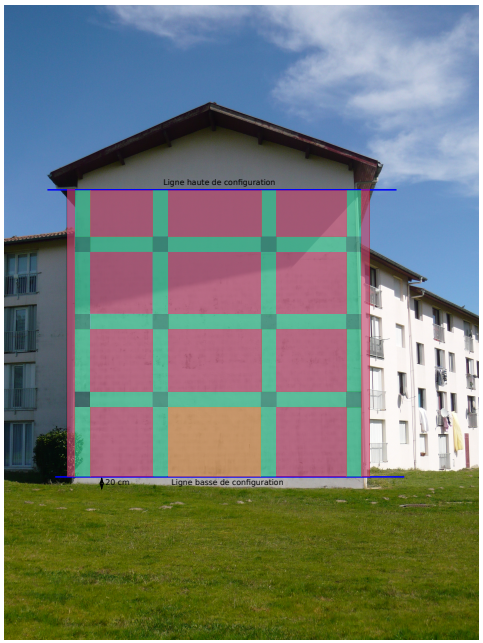
Main Information

- describe structure and geometry of the facade :
  - geometry of the façade :
    - height,
    - length,
    - position of doors, windows, etc
  - areas where metal fasteners can be fixed on the facade.

Façade Main Information

Splitting facades in rectangles

Each façade is split into areas characterized by a load bearing capacity.



Decision Points

Panels Fixing

Regarding these areas and their characteristics

- fixing the panels directly on the facade,
- fixing the panels on the metal profiles.

Impact on BOM and Assembly Process

- metal fastener type and optional metal profiles,
- tasks devoted to metal profiles, such as delivery, assembly and adjustment have to be added.

Decision Points

Modify Decisions at any Steps

Decisions can be changed at any steps of the process :

- Step1 : wood double glass windows for the whole working site (default value)
- ...
- Step5 : wood triple glass windows for a particular component.

Impact on BOM and Assembly Process

Need to cope with default values and particular ones.

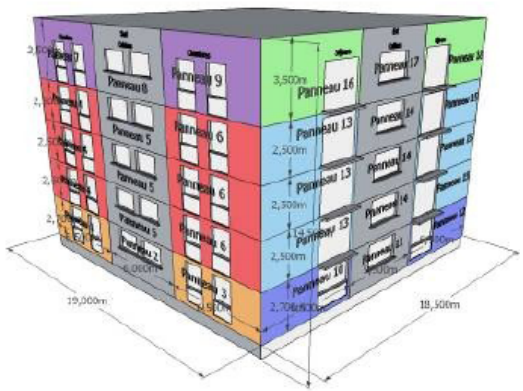
Façades Layout

Different types of interactions

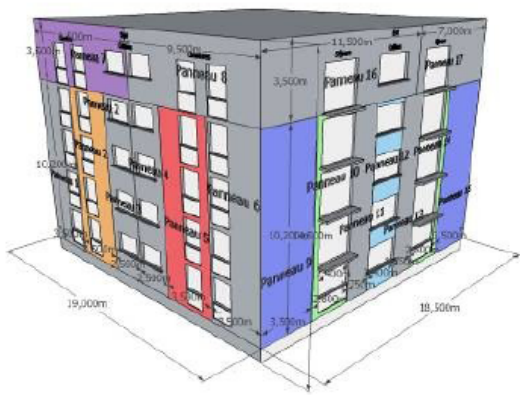
- configurator gives a 1^{rst} solution regarding all the constraints (not an optimal one),
- configurator helps user to draw the layout.

Façades Layout Examples

- **Calepinage 1 : Panneaux de 6 m de longueur corrigé**



- **Calepinage 4 : Grands panneaux verticaux**



Configurable Components

Panels

- tune the insulation thickness
- choose the type of doors and windows
- add windows, doors or solar modules
- modify its dimensions

Angles

- tune the insulation thickness
- modify its dimensions

Different types of CSP

Range of Knowledge

- civil engineering regulations : fire barriers installed between two consecutive stories in order to stop the spread of fire,
- civil engineering know-how that is the core knowledge of the companies involved in the *CRIBA* project,
- working site assembly process to define the suitable way of assembling the new frame and envelope all around the building.

Classical Approaches

Classical Approaches

- variables : discrete, continuous
- constraints : compatibility constraints, mathematical formulae, activity constraints
  - Activation of configurable components (panels, angles, doors, etc).
  - Activation of configurable tasks.
- filtering algorithms : AC, 2B-consistency

Different types of CSP

Several Instances

Need to configure x times configurable components or tasks. x cannot be known in advance...

- blocks, buildings, façades,
- panels, angles, doors, etc
- tasks.

Different types of CSP

Geometric Constraints

Need to prefabricate the panels with a accurate precision.

Global Constraints

Need to cope with constraints that depend on the number of instances of the same class $\Rightarrow$ if the height of the facade is covered with more than one panel, the sum of all the panels heights has to be equal to the facade one.

Conclusion

Synthesis

Building retrofit a century and international challenge

- Develop an interactive configuration system supporting buildings renovation,
- Focus on BOM and main configurable components,
- Identify the types of CSP needed.

To be done...

Still a lot of work to be done

Very beginning of the project

- Collect the knowledge, validate and formalize it,
- Develop relevant algorithms (filtering and layouts),
- Develop GUI for a user preview,
- Test the configurator on real examples.

Thank you for your attention ! ! !

If you have any remarks, feel free to make them...

- Permanent staff at mines Albi-Carmaux : M. Aldanondo, P. Gaborit and É. Vareilles



- PhD Student and Computer Science Engineer : A-F. Barco Santa and Ph. Chantry

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